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Small mammals in farmlands of Argentina: Responses to organic and conventional farming

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ABSTRACT

Despite the important positive role that small mammals have in agricultural systems, mainly through their contribution to food webs, few studies have been conducted on the biodiversity and abundance of this group. Considering that Argentina is one of the most important agricultural regions of the world, our objective was to assess the effect of farming practices (organic vs. conventional) on species richness and abundance of small mammals in border habitats from agroecosystems of central Argentina. We predicted that the effects of farming practices on small mammal populations would vary with the degree of habitat specialization of species. We expected higher species richness and abundance of specialist species in border habitats of organic than on conventional farms. We found that farming practices did not explain species richness; the number of species in border habitats was low with small variation between managements. Management, season and vegetation volume explained abundance of both specialist and generalist species in border habitats, but with additive effects in the former and interactive effects in the latter. During summer, *Calomys musculinus*,*Calomys laucha* and *Akodon azarae* were more abundant in border habitats of organic than on conventional farms. This could be related to the highest reproductive activity of these species in this season, associated to the highest habitat quality of organic border habitats. Also, organic farms may have an important role for specialist species in poor-quality habitats at the beginning and at the end of the reproductive period (spring and autumn). Our results showed a positive trend in small mammal abundance of organic farms in farmlands under intensive agriculture. The differences between Argentinian and European agriculture systems are discussed.

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1. Introduction

One of the most worldwide land-use activities is the conversion of natural landscapes to croplands and pastures (Foley et al., 2005). This activity introduces alterations in habitat quality and suitability, producing agricultural landscapes widely variable in their degree of spatial heterogeneity (Fahrig et al., 2011). More heterogeneous landscapes are characteristic of traditional farming systems where many different production cover types are interspersed with more natural ones. Such patterns contrast with intensive agricultural systems characterized by only a few crop types in large uniform fields (Fahrig et al., 2011; Sirami et al., 2007). Organic farming involves practices similar to traditional farming systems since it has higher levels of habitat heterogeneity, and contains greater densities of uncropped habitats compared to conventional farming (Fuller et al., 2005). Also, insecticides, herbicides, fungicides and inorganic fertilizers are entirely or largely avoided, favouring well-maintained and more suitable border habitats (Norton et al., 2009). This practice is more environmentally friendly than conventional agriculture, which is mainly dependent on external inputs for crop and animal productions (Bengtsson et al., 2005; Tuck et al., 2014).

Studies conducted on plants, insects, birds and mammals have shown that organic farming practices can counteract the negative effects of agriculture intensification (Beecher et al., 2002; Fischer et al., 2011; Holzschuh et al., 2006; Macdonald et al., 2007; Roschewitz et al., 2005). However, the magnitude of their effects seems to vary greatly, particularly among taxa and across landscapes (Batáry et al., 2011; Bengtsson et al., 2005; Winqvist et al., 2012). In simple landscapes (<20% semi-natural areas), the introduction of organic farming would be important for the conservation of biodiversity in farmlands under intensive agriculture (Tscharntke et al., 2005).

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The well-studied European systems are characterised by fine-grained farmland mosaics with relatively small fields, dense networks of hedgerows and roads, and highly intermingled rural and urban areas. This structural complexity differs deeply from the extensive and homogeneous cropland mosaic characteristic of many rural areas in Argentinian agricultural systems, which comprise large arable fields and sparse linear habitat networks (Baldi et al., 2006; Poggio et al., 2010). These linear habitats frequently receive intentional or unintentional spraying of broad-spectrum herbicides from the neighbouring crops (de la Fuente et al., 2010; Ghersa et al., 2002). In intensively managed agricultural landscapes, the maintenance of undisturbed linear habitat networks can attenuate the effects of agricultural intensification by providing suitable habitats for biodiversity conservation (Coda et al., 2014; Gomez et al., 2011; Simone et al., 2010).

In the last decades, the rate of agricultural expansion in Argentina has increased considerably due to technological changes (e.g. no-tillage techniques, genetically modified crops) and market conditions (e.g. global increase in soybean demand) (Baldi and Paruelo, 2008). The farming area dedicated to no-tillage cropping system increased from 2 Mha in 1992–1993 to 27 Mha in 2010–2011 (Aapresid, 2012); and during this process, many field borders were removed to enlarge crop areas (Aizen et al., 2009). In Argentina, the area of organic farmland is small; currently there are 3.6 Mha under this practice, only 240,000 of them are intended to crop production, whereas, the rest is dedicated to pastures for cattle production (SENASA, 2013). Organic farming is characterised by the use of tillage for mechanical control of weeds and no-use of synthetic fertilizers or pesticides, and there is no intentional management on border habitats. On the other hand, conventional management includes external inputs of synthetic pesticides and soluble fertilizers and no-tillage systems where the weed control depends almost exclusively on the use of herbicides (Satorre, 2005).

The effects of agriculture intensification on the diversity and abundance of species could vary with the degree of specialization of species. Specialist species are more dependent on habitat quality and they suffer more from habitat disturbance than generalists, which are able to use other habitats and resources (Filippi-Codaccioni et al., 2010). An increase in agriculture intensification affected small mammal diversity and abundance in the Pampean region (Medan et al., 2011), with habitat generalist species such as the Cricetidae rodent *Calomys laucha* and *Calomys musculinus* being favoured, and habitat specialist species such as *Akodon azarae* being negatively influence (Bilenca and Kravetz, 1995; Cavia et al., 2005; Fraschina et al., 2012). The south-eastern area of Córdoba province (central Argentina, Juárez Celman, Union and Marcos Juárez Departments) has not been free from agricultural intensification, with approximately 1,879,900 ha under crop production, and only 2700 ha of these are under organic management (MAGyA, 2013).

Although many studies have shown the effects of organic farming on biodiversity, they have been heavily biased towards agricultural systems in Europe and North America. In order to have a balanced global assessment of organic farming effects on biodiversity, studies on other regions and at different spatial scales are needed (Tuck et al., 2014). In spite of the important positive role that small mammals play in agricultural systems, mainly through their contribution to food webs (Michel et al., 2006; Salamolard et al., 2000), few studies have been conducted on their biodiversity and abundance (Brown, 1999; Fischer et al., 2011; Macdonald et al., 2000).

Our objective was to assess the effect of farming practices (organic vs. conventional) on species richness and abundance of small mammals in border habitats of agroecosystems of central Argentina. We predicted that the effects of farming practices on small mammal populations would vary with the degree of specialization of the species. We expected higher species richness and abundance of specialist species in border habitats of organic than of conventional farms.

2. Materials and methods

This study was carried out since spring 2011 to autumn 2013 in an agricultural landscape of south-eastern Córdoba province, Argentina (Fig. 1). This period included two annual abundance

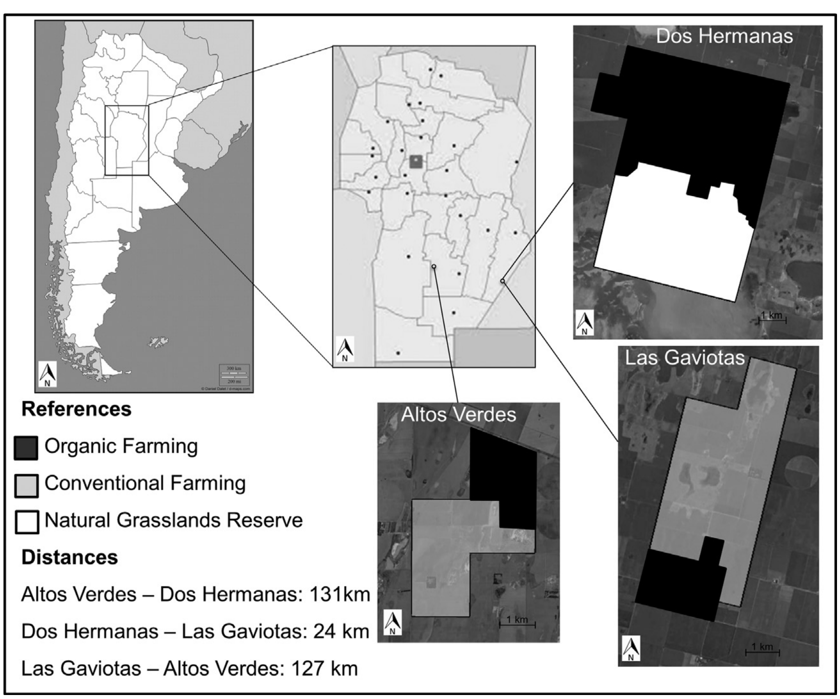

Fig. 1. Study area, agricultural systems of south-eastern Córdoba province with the three farms (Dos Hermanas, Las Gaviotas and Altos Verdes) that include organic and conventional managements, with distances between them.

cycles of rodents. Cycle 1 (AC1): November 2011 (spring in the Southern Hemisphere), February–March 2012 (summer) and May–June 2012 (autumn); cycle 2 (AC2): November 2012, February–March 2013 and May–June 2013. This region is a land mosaic where the original flora is restricted to uncultivated border habitats. These linear habitats support a mixed vegetation type dominated by native and invasive herbaceous species. The most frequent crop sequences are wheat–soybean or soybean–maize (as alternate single summer crops per year with a winter fallow), even though the soybean monoculture as a single summer crop per year is also a common practice (Puricelli and Tuesca, 2005; Satorre, 2005).

In this region, the small mammal assemblage is mainly represented by the Cricetidae rodents *C. musculinus*, *C. venustus*, *C. laucha*, *A. azarae*, *A. dolores*, *Oxymycterus rufus* and *Oligoryzomys flavescens* (Simone et al., 2010). Rodent species were ranked from generalists to specialists considering species-specific habitat specialization; ranging from habitat generalist (species occur in almost all habitats within the agriculture landscape) to habitat specialist (species occur in habitats with high vegetation cover): *C. musculinus*, *C. laucha*, *A. azarae*, *O. flavescens*, *C. venustus*, *A. dolores* and *O. rufus* (Martínez et al., 2014).

Considering the low number of hectares under organic farming in Argentina, and particularly in south-eastern Córdoba province, we were able to survey the entire surface under this management. Three farms were sampled: Las Gaviotas (Postel S.A.) (33°50′S, 62°39′W) (1689 ha), Dos Hermanas (Foundation Rachel and Pamela Schiele) (33°39′S, 62°30′W) (4023 ha) and Altos Verdes (Huanqui S.A.) (33°18′S, 63°51′W) (1010 ha) (Fig. 1 and Fig. A1). Dos Hermanas farm includes a natural grassland reserve of 1922 ha and a productive area which has been under organic management since 1992 (Table 1, Fig. 1 and Fig. A1). Las Gaviotas and Altos Verdes farms have both organic and conventional managements (Table 1, Fig. 1 and Fig. A1); organic plots of these two farms have been under this management for 10 years. Weeds of plots under organic management were mechanically controlled using disk plough, chisel plough, roll and weeder, whereas farms under conventional management used herbicides (glyphosate, atrazine, acetochlor, nicosulfuron, 2,4-D, chlorimuron and metolachlor) for weed control. Other external inputs as fertilizers (sulfur, urea and ammonium) and insecticides (chlorpyrifos, alphametrin, cyclopropane carboxylate, endosulphan and lambdacyalothrine) are regularly used in conventional plots; while fungicides (epoxiconazole, pyraclostrobin, azoxistrobina, difenoconazol) are used as required. During the study period the main crops were soybean and maize, both in organic and conventional farms. Organic fields are certified by private companies, OIA (Organización Internacional Agropecuaria, 2014) for Las Gaviotas and Argencert (Argencert, 2014) for Altos Verdes and Dos Hermanas. Both private companies operate as certifier of crop and livestock organic products. To characterise each farm by management and annual cycle we calculated the percentages of arable land (cereal crops), grassland, pasture (alfalfa) and forest relict. We estimated habitat diversity with the Shannon index using percentages of arable land, grassland, pasture, forest relict and border habitat. In general, this index showed higher values for organic than for conventional farms (Table 1).

Our study was conducted in border habitats of organic and conventional farms, a border is a 1.5–2.5 m wide vegetation strip located in the inner margin of fields. The use of land on both sides of the border was classified as: crop/crop (C/C, fields cultivated with soybean or maize) or crop/pasture (C/P, fields cultivated with soybean or maize/fields used for cattle).

Capture, mark and recapture (CMR) trapping sessions were conducted during spring, summer and autumn for AC1 and AC2, over two weeks in each session. Altos Verdes was sampled during the first week and Dos Hermanas and Las Gaviotas during the second week; for each week, trapping was conducted during four consecutive nights. A total of 116 and 106 trap lines were placed in AC1 and AC2, respectively. Each line had 20 traps similar to Sherman live-traps, with a trap every 10 m in the middle of a border. Eight and seven additional trap lines of 20 traps each were placed in organic and conventional crop fields in AC2. These lines were located parallel to border lines at 15 m within crop fields (see details in Appendix: Table A1). The minimum distance between lines was 300 m to avoid correlation between neighbouring lines and the influence of neighbouring farms (Gomez et al., 2011; Sommaro et al., 2010). Traps were baited with a mixture of peanut butter and cow fat.

In each line, vegetation measurements were made using a quadrat of 1 m^2 centred in a trap, 10 traps were surveyed. Variables recorded in each quadrat unit were (1) percentage of green cover, (2) percentage of plant litter, (3) height (cm) of green cover and plant litter and (4) vegetation volume (m^3). Height was obtained as the mean value of ten measurements randomly registered in the 1×1 m quadrat and vegetation volume was estimated as shelter $\times$ height, where shelter was the combination of the percentage of green cover and plant litter. Values from the ten quadrats were averaged to obtain a unique value of each variable for each line. Trapped animals were identified, sexed, weighed and ear-tagged. Body and tail length were also registered. We estimated the abundance of each species as the number of individuals in each trap-line.

Table 1
Description of sampled farms by management and annual cycle. Mean plot size (ha) ± standard deviation (SD), total percent area covered by arable land, pastures, grasslands, border habitats, forest relicts, and habitat diversity (Shannon index) are shown. AC1: from November 2011 to May 2012; AC2: from November 2012 to May 2013.

	Annual cycle	Total (ha)	Mean plots (ha) ± SD	Arable land (%)	Pastures (%)	Grasslands (%)	Borders (%)	Forest relict (%)	Habitat diversity
Organic									
Altos Verdes	AC1	346	33.70 ± 19.46	12.74	0	76.71	1.58	4.63	0.67
	AC2		33.70 ± 19.46	28.37	5.79	55.29	1.58	4.63	1.06
Las Gaviotas	AC1	330	64.80 ± 19.45	66.66	31.29	0.45	1.13	0.21	0.73
	AC2		64.80 ± 19.45	53.65	44.55	0.45	1.13	0.21	0.78
Dos Hermanas	AC1	4023	53 ± 24.02	16.13	21.23	49.81	1.24	0.48	1.05
	AC2		53 ± 24.02	11.86	24.06	51.25	1.24	0.48	1.02
Conventional									
Altos Verdes	AC1	664	47.50 ± 10.48	66.01	0	28.15	1.31	1.20	0.74
	AC2		47.50 ± 10.48	74.14	0	20.02	1.31	1.20	0.65
Las Gaviotas	AC1	1359	69.40 ± 33.07	76.11	0	14.99	1.09	1.10	0.59
	AC2		69.40 ± 33.07	67.79	0	23.21	1.09	1.10	0.70

For vegetation analyses we used green cover, plant litter and vegetation volume as response variables, and implemented the Linear Mixed Models (LMMs), with the *lme* function. We included farming (organic and conventional) and season (spring, summer and autumn) as fixed factors and annual cycle (temporal pseudoreplication) and farm (spatial pseudoreplication) as random factors. We used random factors to control for the lack of independence between observations. Random effects have factor levels that are drawn from a large population in which the observations differ in many ways, but we do not know exactly how or why they differ. Thus, it does not make any sense to concentrate on estimating means of a small subset of factor levels (Crawley, 2007). We evaluated all possible models containing additive and interaction effects. The null model with intercept only was also considered. Models were compared using Akaike Information Criterion, corrected for small sample size (AICc), ΔAICc values and Akaike weights. To estimate the relative variable importance and weighted averages of parameter estimates we averaged models with ΔAICc ≤ 3 that provide substantial empirical evidence for the model (Burnham and Anderson, 2002; Fischer and Schröder, 2014).

Abundance of each species and richness were analysed using Generalized Linear Mixed Models (GLMMs) with the *glmer* function, and for richness we used the Poisson distribution. The abundance analyses were performed with the most abundant species: the generalists *C. musculinus* and *C. laucha* and the specialist *A. azarae*. For *C. musculinus* and *C. laucha*, the response variable was the number of individuals, and we used the Poisson distribution. Due to the fact that *A. azarae* was not captured in several trap lines, for this species we considered presence/absence of individuals in each line as the response variable, and we used the binomial distribution. Farming management (M), season (S), land use on both sides of the border (U) and vegetation volume (V_v) were considered as fixed factors. We included farm and cycle as random factors. The set of models contained explanatory variables (M, S, U and V_v), the additive effects of two, three or four predictor variables and the interaction effects considering only those models with biological meaning ($M \times V_v$; $S \times V_v$; $M \times S$; $M \times U$; $V_v \times U$ and $M \times S \times V_v$). The interaction models were performed to avoid problems with the number of parameters to be estimated in the analyses and considering only those models with biological meaning. The null model was also evaluated. Model selection was performed using the previously described procedure. We used R 3.0.2 software (R Development Core Team, 2013) for all analyses.

3. Results

The best statistical models for green cover and plant litter included the interaction effects of season and management, whereas for vegetation volume it included additive effects of these variables (Appendix: Table A2). Green cover was higher in organic than in conventional farms, but seasonal variations were higher in the latter. Percentages of plant litter were higher in conventional than in organic farms, there was little plant litter during spring and summer in organic farms. In all seasons, vegetation volume showed higher values in borders of organic farms (Fig. 2a–c).

We trapped a total of 663 individuals corresponding to seven species in 17,760 trap-nights, 309 and 354 individuals in border habitats in AC1 and AC2, respectively (Table 2). Weights and body lengths by species and sex are detailed in Appendix: Table A3. The total abundance of rodents was similar in organic and conventional farms of both cycles (Table 2). The abundance of the specialist

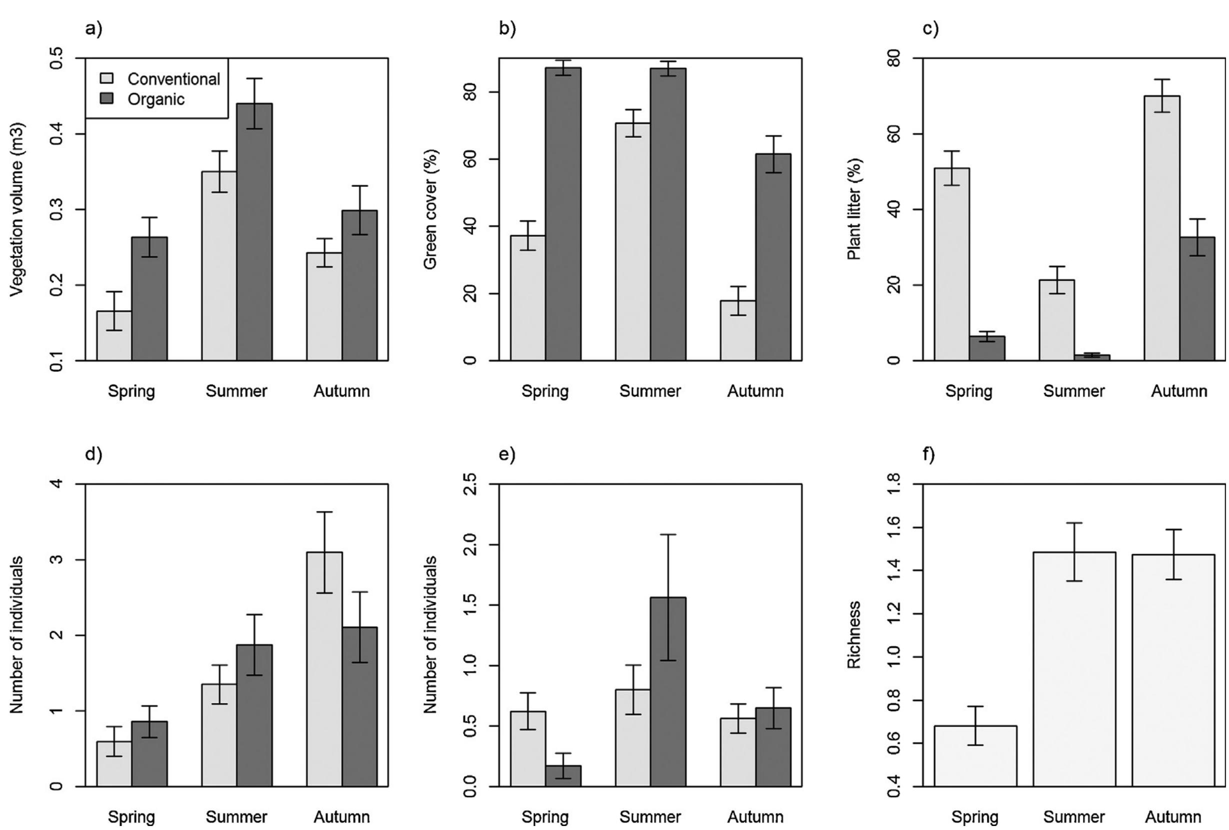

Fig. 2. (a) Vegetation volume (mean ± SE) and percentages of (b) green cover (mean ± SE), (c) plant litter (mean ± SE) in border habitats under organic or conventional managements by season. Number of individuals (d) *Calomys musculinus*, (e) *Calomys laucha* in border habitats under organic and conventional managements by season. (f) Small mammal species richness in border habitats by season.

Table 2
Total small mammal abundance, species richness and abundance of captured species in organic and conventional border habitats for AC1 and AC2. Small mammal species were ranked from generalists to specialists considering species-specific habitat specialization. Mean values ± standard deviation (M ± SD). The number of individual captured in lines placed within crop fields is shown in brackets.

	AC1				AC2			
	Organic		Conventional		Organic		Conventional	
	M ± SD	Total	M ± SD	Total	M ± SD	Total	M ± SD	Total
Abundance	2.54 ± 3.62	160	2.37 ± 2.77	149	2.90 ± 3.51	175	3.22 ± 3.60	179
Richness	1.11 ± 1.14	5	1.13 ± 0.94	6	1.17 ± 1.01	5	1.20 ± 1.01	5
C. musculinus	1.05 ± 1.75	66	1.40 ± 2.18	88	1.80 ± 2.46	108(9)	2.09 ± 2.88	115(3)
C. laucha	0.97 ± 2.24	61	0.68 ± 1.04	43	0.35 ± 0.82	21(3)	0.64 ± 0.99	35(6)
A. azarae	0.21 ± 0.48	13	0.14 ± 0.43	9	0.52 ± 1.28	31	0.42 ± 1.03	23(1)
O. flavescens	0.11 ± 0.32	7	0.02 ± 0.13	1	0.23 ± 0.72	14	0.07 ± 0.26	4
C. venustus			0.03 ± 0.25	2				
O. rufus					0.01 ± 0.13	1	0.04 ± 0.19	2

species *A. azarae* was higher in border habitats of organic than of those in conventional farms; the other specialist species (*O. flavescens*, *C. venustus* and *O. rufus*) had low captured numbers during the study. The most captured species in border habitats of both managements were the generalists *C. musculinus* and *C. laucha*. Besides nine *C. musculinus* and three *C. laucha* were captured in 640 trap-nights within crop fields in organic farms, and one *A. azarae*, three *C. musculinus* and six *C. laucha* were captured in 560 trap-nights in conventional farms (Table 2).

Since for richness analyses, four models had similar statistical support (ΔAICc ≤ 3; Table 3), we used weighted parameter estimates for variables using model averaging. Finally, to explore the relative influence of the predictor variables, we used hierarchical partitioning as implemented in the hier.part package. The relative influence of each predictor variable was: vegetation volume (coefficient = 1.44, SE = 0.45; % I_y = 63.49), season (spring: coefficient = −0.74, SE = 0.25; summer: coefficient = −0.23, SE = 0.23; % I_y = 35.34), management (organic: coefficient = 0.0147, SE = 0.2435, % I_y = 0.6786) and land use (C/P: coefficient = −0.0519, SE = 0.1247, % I_y = 0.4914). Richness was lowest in spring corresponding to the lowest vegetation volume (Fig. 2a and f).

GLMM analyses revealed that management in interaction with season and vegetation volume had a significant effect on *C. musculinus* and *C. laucha* abundance (Table 3). During summer, the abundance of generalist species was higher in border habitats of organic than on conventional farms. These findings were in agreement with the highest values of vegetation volume registered during this season. For the other seasons, the relationship between management and abundance varied by species. In spring, *C. laucha* was more captured in borders under conventional management, and *C. musculinus* showed little difference between farming practices. On the contrary, during autumn *C. laucha* did not show differences of abundance between managements and *C. musculinus* was more abundant in borders of conventional farming (Fig. 2d and e). For the specialist *A. azarae*, we found that three models had similar statistical support (ΔAICc ≤ 3; Table 3); thus, we applied model averaging and hierarchical partitioning. The relative influence of each predictor variable was vegetation volume (coefficient = 4.3010, SE = 1.1081; % I_y = 60.7507), season (spring: coefficient = −1.5877, SE = 0.5773; summer: coefficient = −0.7520, SE = 0.4451; % I_y = 34.3590), management (organic: coefficient = 0.3819, SE = 0.4206, % I_y = 4.8903) and land use (C/P: coefficient = 0.0755, SE = 0.4078, % I_y = 0.9774). During spring, the values of vegetation volume were lowest and we captured *A. azarae* only in border habitats of organic farms. During summer, *A. azarae* had a higher frequency of occurrence in organic farms that made up 28.13% (caught in 9 trap lines from the total of 32). In conventional farms, individuals of this species were caught in 8 trap lines from the total of 40 (20%). During autumn, *A. azarae* was captured in 10 of 37 trap lines (27.03%) and 10 of 41 trap lines (24.39%) of organic and conventional farms, respectively.

Table 3
Model selection, based on AICc comparison, of Generalized Linear Mixed Model (GLMM) describing species richness and rodent abundance. *S*: season; *M*: management; V_v: Vegetation volume; *U*: land use on both sides of the border.

	Best model	AICc	ΔAICc	*K*	Deviance
Richness	$S+V_v$	202.7288	−1.9589	6	190.3381
	$S+V_v+U$	204.6877	−0.0216	8	190.1644
	$S+V_v+M$	204.7093	−0.3409	8	190.1860
	$S\times V_v$	204.3684	−3.8319	6	187.6924
Species					
C. musculinus	$M\times S\times V_v$	472.9381	−14.0575	9	442.9091
C. laucha	$M\times S\times V_v$	365.5933	−10.3569	9	335.5644
A. azarae	$S+V_v$	196.8076	−1.3216	6	184.4169
	$M+S+V_v$	198.1292	−0.778	8	183.6059
	$U+S+V_v$	198.9074	−1.2870	9	184.3840

4. Discussion

There is a general consensus that organic farming increases species richness of arthropods, birds, microbes and plants (Tuck et al., 2014); however, the evidence is scarce in groups with lower species numbers as small mammals in agroecosystems (Fischer et al., 2011). Our study aimed to compare effects of conventional and organic farming on species richness and abundance of small mammals in border habitats of Argentinian agroecosystems.

We expected that border habitat on organic farms would have higher richness and abundance of specialist species than those of conventional farms. However, our results showed a more complex relationship between response variables and management. Farming practices did not explain richness, as the number of species per border was low with small variation between managements. Fischer et al. (2011) found that organic farming had a positive effect on species richness in simple landscapes (>80% of arable land) at a small spatial scale (100 m). In our study, the percentages of arable land were always lower in organic than in conventional farms; however, this was not enough to produce an effect on species richness at the spatial scale considered in this study.

In agricultural systems, the reduction of agrochemical application increases the diversity of plants and invertebrates in field borders (Tew et al., 1992; Frieben and Kopke, 1995). Also, fields under organic management generally exhibit higher abundance and species richness of weeds and invertebrates, regardless of the arable crop being grown (Frieben and Kopke, 1995; Hald, 1999; Macdonald et al., 2000; Hole et al., 2005). Although most of these results are from European systems, they may also apply to organic farms in Argentina that do not use synthetic pesticides and fertilizers (Coda et al., 2014). It is expected that this type of management renders crop fields and border habitats of organic farms more suitable habitats for a variety of taxa. Particularly, our findings showed that habitat quality of organic farm borders was the highest due to the increased vegetation volume mainly comprised of green cover. On the other hand, border habitat quality on conventional farm was the lowest as a consequence of the small vegetation volume manly comprised of plant litter.

Management, season and vegetation volume explained abundance of both specialist and generalist species in border habitats, but with additive effects in the former and interactive effects in the latter. The highest habitat quality of organic farm borders explains the higher captures of specialist *A. azarae* in the summer, whereas, during the spring, it was only captured in those border habitats. The absence of this species in border habitats of conventional farms most probably is due to the low suitability of these habitats. The higher captures of the specialist species *A. azarae* in more vegetated and stable habitat is in line with previous studies of this species (Andreo et al., 2009; Busch et al., 2001). During autumn, the border habitat quality is lower due to habitat perturbation produced by harvest in both management. Consequently, capture differences for this specialist species between management was less noticeable during autumn. During summer, the response of generalist species was similar to the specialist species, with higher numbers of *C. musculinus* and *C. laucha* in highest quality habitats of organic farm borders. During spring and autumn, when border habitat quality decreases, organic management appears to have less influence on the abundance of the generalist species. The higher captures of generalist species in trap lines located in crop fields of organic farms may be in response to their highest habitat quality. Indeed trap success of *C. laucha* was higher in crop fields than in borders of organic farms. Hodara and Busch (2010) observed that this species uses crop fields with a high weed cover, as would be the case in crop fields of organic farms.

In a recent study conducted in European agroecosystems, Fischer et al. (2011) found that complex landscapes increased abundance, richness and diversity of small mammals in conventional compared to organic fields. Complex landscapes appear to support small mammal colonization of crop fields and may increase habitat connectivity (Alain et al., 2006; Fischer et al., 2011). In Argentina, mean plot sizes of agricultural systems are larger than those of European systems (in our study, mean plot size >30 ha versus <10 ha in average in European systems, e.g. Fischer et al., 2011), fully exceeding dispersal scale of rodent species (Gomez et al., 2011; Sommaro et al., 2010). Thus, crop fields in conventional farms with scarce weed cover could not connect suitable habitats for small mammals nor provide shelter from predators; reinforcing the importance of border habitats as corridors and as source of resources for long-term survival and reproduction in these agroecosystems (Coda et al., 2014; Gomez et al., 2011; Sommaro et al., 2010). Although, mean plot sizes of organic farms are similar to those of conventional ones, the formers could provide more resources (coverage and food) for small mammals, both in border habitat and crop fields; which could be related to the exclusion of external inputs (Coda et al., 2014). If this is the case, we expected that organic farming has positive effects on abundance and richness of small mammals in simple landscapes such as Argentinian farmland under intensive agriculture. We registered higher rodent numbers in organic farms only during summer, when the three studied species were more abundant in border habitats of organic than on conventional farms. These findings could be related to the highest reproductive activity associated to this season and the best habitat quality of organic border habitats (Coda et al., 2014). Also, this better habitat quality may be related to a higher movement rate towards more suitable border habitats of organic farms.

5. Conclusions

The overall benefits of organic farming for biodiversity conservation have been intensely debated during the last years (Bengtsson et al., 2005; Hole et al., 2005; Tuck et al., 2014). However, to our knowledge, this is the first study that investigates the effect of organic management on species richness and abundance of small mammals in Argentina. Our study intended to quantify the differences between organic and conventional management using small mammals as a study model.

Our results showed that organic management in farmlands under intensive agriculture has no effect on species richness, has a positive influence on specialist species abundance and show no consistent effect on generalist species abundance. Since our abundance and species richness estimates were low, it is possible that they were not enough to show clear statistical effects of organic farming, thus our results should be considered carefully.

Given that small mammal specialist species are more dependent on habitat quality (measured as green cover), their abundance could be a good indicator of habitat quality in farmlands, as it was previously emphasised for farmland birds (Filippi-Codaccioni et al., 2010). Considering the important positive role that small mammals have on food webs in agricultural systems, the maintenance of high population numbers may be important for biodiversity conservation. Although our study may suggest that the implementation of organic farming may be a good conservation strategy for small mammals in Argentina, future studies at different spatial scales, are needed in order to assess the interaction between landscape complexity and farming practice.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2015.05.007.

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Appendix

Figure A1: Study area, agricultural systems of south-eastern Córdoba province with the three farms that include organic and conventional managements, with distances between them (see KMZ file).

Table A1. Distribution of the trap lines by cycle (AC1: annual cycle 1; AC2: annual cycle 2), season, management (O: organic; C: conventional) and farm. Numbers of additional lines placed within crop fields are shown in brackets.

	AC1						AC2					
	Spring		Summer		Autumn		Spring		Summer		Autumn	
	O	C	O	C	O	C	O	C	O	C	O	C
Altos Verdes	9	10	4	10	7	10	5	7	7	9	8(2)	10
Dos Hermanas	8	-	8	-	8	-	7(2)	-	8(2)	-	8(1)	-
Las Gaviotas	3	11	3	11	3	11	3	9(2)	2	10(3)	3(1)	10(2)
Total	20	21	15	21	18	21	15	16	17	19	19	20

Table A2. Model selection, based on AICc comparison, of Linear Mixed Models (LMMs) describing vegetation variables. S: season; M: management.

Vegetation variables	Best model	AICc	ΔAICc	K	Deviance
Green cover	S * M	2037.34	0	8	2018.47
	S + M	2062.88	-25.56	7	2048.35
	S	2134.45	-97.13	5	2122.06
	M	2147.31	-109.99	3	2137.03
	Null	2200.23	-162.91	3	2192.04
Plant litter	S * M	2002.98	0	8	1984.11
	S + M	2021.24	-18.26	7	2006.71
	S	2086.92	-83.94	5	2074.53
	M	2120.87	-117.89	3	2110.59
	Null	2166.76	-163.78	3	2158.58
Vegetation volume	S + M	-130.73	0	7	-145.27
	S	-127.17	-3.56	5	-139.56
	S * M	-118.81	-11.92	8	-137.66
	M	-105.65	-25.08	3	-115.93
	Null	-105.15	-25.58	3	-113.33

Table A3. Mean values (M) and standard deviation (SD) of weight (W) and body length (BL) by sex of species captured in border habitats of organic and conventional farms for AC1 and AC2. Rodent species were ranked from generalists to specialists considering species-specific habitat specialization.

		AC1				AC2			
		Organic		Conventional		Organic		Conventional	
	Sex	W (M±SD)	BL (M±SD)	W (M±SD)	BL (M±SD)	W (M±SD)	BL (M±SD)	W (M±SD)	BL (M±SD)
C. musculinus	♂	15.95 ± 7.72	78.90 ± 14.92	17.87 ± 6.70	84.98 ±10.88	16.57 ± 7.70	83.28 ±13.26	14.13 ±7.59	78.24 ±12.35
	♀	17.48 ± 8.90	80.11 ± 14.57	13.38 ± 5.66	77.10 ± 14.65	15.39 ± 7.61	82.16 ±14.29	12.73 ± 5.12	76.71 ±11.20
C. laucha	♂	14.63 ± 4.86	78.06 ± 9.72	12.46 ± 4.05	75.46 ± 9.06	11.46 ± 4.71	70.92 ±9.84	12.79 ± 5.61	76.75 ±11.48
	♀	16.15 ± 6.57	79.54 ± 12.03	11.54 ± 4.70	72.67 ± 9.60	11.94 ± 4.57	77.75 ±13.37	13.88 ± 5.87	75.25 ±10.28
A. azarae	♂	22.93 ± 4.45	96.43 ± 6.24	23.81 ± 2.71	99.38 ± 4.96	19.94 ± 5.06	96.13 ±9.26	20.83 ± 5.89	94.42 ±10.57
	♀	19.83 ± 5.46	92.17 ± 12.32	14.00(n=1)	86.00(n=1)	18.33 ± 4.48	95.27 ±7.52	19.41 ± 8.13	88.91 ±10.97
O. flavescens	♂	15.42 ± 6.84	76.83 ± 12.17	15.00(n=1)	92.00(n=1)	13.17 ± 2.14	77.17 ±8.98	10.50 ± 1.73	71.00 ±10.98
	♀	7.50 (n=1)	57.00(n=1)			14.69 ± 4.57	83.50 ±13.27		
C. venustus	♂			47(n=1)	120.00(n=1)				
	♀			34(n=1)	110.00(n=1)				
O. rufus	♂					110(n=1)	151(n=1)	100.00 ± 14.14	141.50 ±28.99